

Implementation of the Dead-Time Free F1 TDC in the COMPASS Detector Readout

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Abstract

In the scope of the COMPASS experiment a multi-purpose, high rate capable TDC with digitisation width of 60 ps has been developed. The integration into the readout system and the flexible input of the CATCH readout driver is presented.

Key words: TDC; readout driver; front-end electronics; VME

The COMPASS experiment at CERN will investigate the hadron structure by deep inelastic muon scattering and hadronic production processes. One central issue of the experimental effort will be the measurement of the contribution of gluons to the nucleon spin. To reach this objective a demanding state-of-the-art double-stage spectrometer with large geometrical and dynamical acceptance is being set-up and commissioned through the year 2000.

1 Overview of the readout architecture

The large active detector volume, the necessary expandability to perform different physics experiments and the upgradeability during the longevity of the experiment requires a scalable and distributed readout system with federal event building (Figure 1). The high particle flux from the traversing beam at intensities of $2 \cdot 10^8$ particles per spill (2.4 s) requires dead-timeless readout with digitisation immediately at the detector. Data are stored on the front-end boards in random access memories or pipelines for about $2 \mu\text{s}$ until trigger

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decisions have been taken. Only those hits are transmitted to the master event-builder which are time correlated to a physics trigger event. Hence background data are suppressed at an early stage of the readout chain, which reduces the necessary bandwidth significantly down to several Gigabytes per spill.

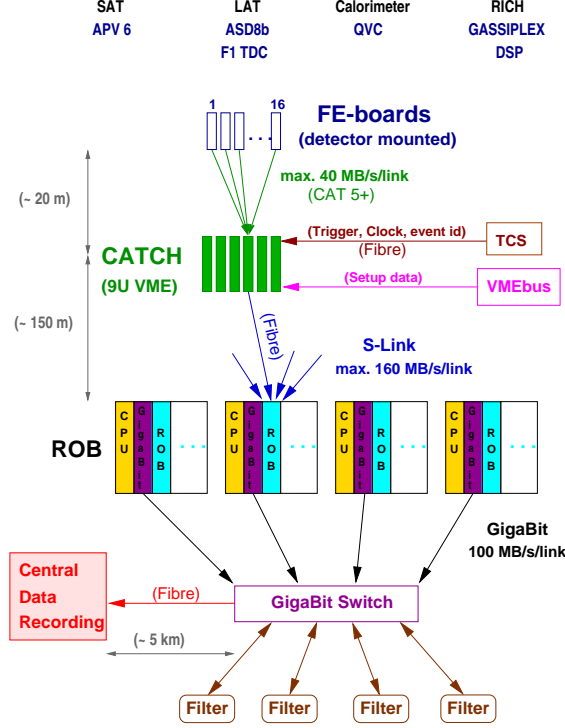


Fig. 1. The architecture of the COMPASS detector readout.

The trigger rate depends on the physics reactions to be studied and is in the range of 10–100 kHz. Trigger signals are distributed synchronously to a 38.88 MHz clock via optical fibres from the trigger control system (TCS) laser crate. Additional event information like spill and event numbers, time synchronisation signal and begin- and end-of-spill flags are transmitted through the same fibre by time multiplexing.

The readout driver named CATCH (COMPASS Accumulate, Transfer and Control Hardware [1]) serves as a common interface between the detector-specific front-end boards, the trigger control system and the readout buffers. Data which belong to one event are combined in a local sub-event building process and consistency checks are performed on the data integrity. The sub-events are transmitted via a fast optical link to readout buffers, which can store all data from at least one spill. Sub-events are combined and transmitted via Gigabit Ethernet to filter computers. Here the final event-building is performed, events are partly reconstructed and, based on physics cuts, data may be reduced by a factor of 5 to 10. Finally a continuous rate of 30 MByte/s of event data can be transferred to the central data recording facilities at CERN, where the events will be stored in an Objectivity/DB data base. The total

amount of data accumulated each year will be about 300 Terabyte.

2 F1-TDC

To be in compliance with a dead-time free data-digitisation and the time resolution requirements of the detectors we developed a new TDC-chip. This device can be easily adapted to the conditions of different detector types [2]. The F1-TDC, produced in $0.6\ \mu\text{m}$ sea-of-gates technology, supports basically three modes: In the high rate option ($> 6\ \text{MHz}$ input rate) the TDC chip provides a digitisation width of 60 ps on four input channels at a double pulse resolution of about 18 ns. The standard mode delivers a digitisation unit of about 120 ps on eight inputs per chip at a dynamic range of 16 bits. The latch mode implements a 32 channel low resolution ($>4.7\ \text{ns}$) readout for multi wire proportional chambers. In all modes the hits, which are time correlated to the trigger, are selected for readout from an internal buffer.

We have chosen two options for interfacing the F1-TDC to the CATCH read-out driver: For the high rate detectors like scintillating fibres, trigger hodoscopes and the beam momentum stations, the TDCs are placed on mezzanine cards, which are mounted on the CATCH, allowing for a readout speed of 120 MByte/s. Each mezzanine card hosts four TDC chips and supports 32 differential inputs in standard resolution or 16 inputs in high resolution mode (software selectable). The straw tubes, drift chambers and micromega chambers have the TDCs mounted on the front-end boards operated in standard resolution mode, as well as the multi wire proportional chambers with the F1-chip in latch mode. In case of the micromega chambers [3] both leading and trailing edges are read-out allowing for noise suppression and walk correction by measuring the time over threshold. For all front-end mounted F1-TDCs a DAC interface is used to set the thresholds of the external discriminators. Up to eight TDCs are placed on one front-end board and read-out through a common bus, which interfaces to a HOTLink serialiser chip.

3 CATCH readout driver

Four exchangeable input mezzanine cards mounted on the 9U VME module provide a highly flexible input interface (Figure 2). At the moment we have developed three different types of mezzanine cards following the IEEE CMC standard:

One type receives digitised data from up to four different front-end boards. For this mezzanine card we use the HOTLink serialising chip and a 600 MHz

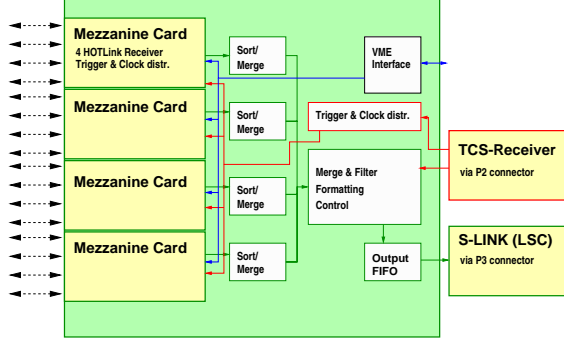


Fig. 2. CATCH schematic.

differential twisted pair line to achieve 400 MBaud sustained input data rate. The same patch cable is used to transmit trigger, time synchronisation and a power-up reset signal on a common line. Through a third and fourth line the reference clock and initialisation data, respectively, are distributed to the front-end boards. This card is also available with a fibre optical link to replace copper cables.

Another type of mezzanine card hosts four F1-TDC chips resulting in a 128 channel TDC module. A 32 channel 300 MHz dead-time free and trigger-latency correcting scaler is implemented on the third mezzanine card.

While framed data are transmitted at a maximum throughput of 160 MByte/s to the readout buffer via a S-LINK module [4], an independent spy buffer can be used to access events via the VME bus at a lower data rate. This allows for an easy setup of a stand alone DAQ without S-LINK and spill buffer at test beams.

The live insertion of the CATCH and plug & play feature for front-end and mezzanine boards greatly enhances the maintainability of the system and eliminates miscabling. The front-end boards transmit their identification and position on the detector to the CATCH, which stores this information in the geometry database and receives the corresponding initialisation data from the calibration database.

Acknowledgements

This work would be impossible without the formidable support of the local electronic workshop and engineer team. We deeply appreciate the many stimulating discussions with our colleagues from the COMPASS collaboration involved in front-end electronics development. The developments described in this report are supported by the German Bundesministerium für Bildung und Forschung.

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